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How Students View Social Change Through A Robotics Outreach Experience

Alejandra Noemi Vasquez, Tufts University
Trevion S Henderson, Tufts University

Trevion Henderson is Assistant Professor of Mechanical Engineering at Tufts University. He earned his Ph.D. in Higher Education at the University of Michigan.

Yara Zaza, Tufts University

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Introduction

Community-based, service-learning experiences are thought to be high-impact practices because they foster important learning outcomes, including students' understanding of their social responsibilities and civic engagement [1]. In engineering, these outcomes also included sociotechnical learning outcomes, such as learning to engage people and communities and designing for social justice [2]. Such outcomes have been challenging to produce in engineering education, which is often critiqued for its tendency towards technocentric learning experiences [3-4]. While existing research has suggested that service-learning and civic engagement opportunities in engineering can foster positive outcomes [5], scholars have argued that college students are an underutilized resource in movements for social change [6-7].

We began by reviewing conventional educational practices for engaging people and communities in engineering. Critiques of such practices abound. First, scholars posit that conventional, classroom-based approaches position students as objects of change, where educational activities are designed to shape their ways of thinking, knowing, and doing, instead of subjects of change, where students are agentic sociopolitical actors using their knowledge and resources to mutually benefit themselves, their institutions, and local, regional, state, national and global communities. In such scenarios, engineering education research suggests institutional actors (e.g., faculty, students) may engage in practices that exploit community needs for student learning in ways that do not benefit the people and communities at the center of community-engaged learning experiences. Thus, scholars have established a need for engineering educators to develop processes and practices for engaging students as subjects of change that support community members' autonomy, self-determination, and power in such projects [8].

This research examined student reflection following participation in a community outreach program—Community Robotics (CR)—where college students were assigned to local schools to support robotics education across local and national contexts. The CR program resisted conventional approaches in two ways. First, while many educational research projects engaged in approaches where institutional actors developed and ported prescribed educational opportunities (e.g., teacher professional development, prescribed student learning activities) to community members, our goal was to develop educational activities that reflected context-sensitive teacher, school, and community needs. Second, we sought to engage college students not as employees implementing faculty-prescribed learning experiences, but as researchers, developers, and community-engaged leaders designing and implementing robotics education across various contexts. We presupposed that such experiences might position students to examine the challenges that are specific to their assigned schools, fostering a deeper understanding of the people and communities in which they work, as well as the role of their work for fostering social change. The purpose of this paper was to examine college students' learning outcomes as a component of the broader outcomes (e.g., teacher development, high school student learning) that we evaluate in the CR program. This paper was guided by the following research question:

1. How does community engagement shape students' beliefs about the role of engineers in social change?

Literature Review

Service Learning versus Community Engagement

This research described a community engagement program between a private, 4-year institution and a set of K-12 schools across the United States. Existing literature used several terms to describe learning experiences wherein students participate in community-based learning activities (e.g., service learning, community outreach, community engagement), each of which differed in the types of learning activities they describe and the types of learning outcomes they are thought to produce. While we considered *service learning* to describe the CR program, we believed it was inaccurate because the learning goals were not explicitly designed into the program, and students did not receive the traditional academic credit associated with service learning classes [9]. Moreover, Oakes [9] argues that the term service-learning implies that the service and learning goals are equal in weight, thus improving the service experience for other participants. Similarly, community outreach implied a one-way process where the community received a benefit, usually through resources or information [10]. Instead, we opted for community engagement to describe CR's purpose, defined as a "collaboration between institutions of higher education and their larger communities (local, regional/state, national, global) for the mutually beneficial exchange of knowledge and resources in a context of partnership and reciprocity" [11]. Community engagement matched our goal to create partnerships that examine and mitigate power dynamics between the various stakeholders (the school and CR) [12].

Motivations and Outcomes of Service Programs

Existing literature suggested students' motivations for participation in community-engagement experiences arose from various factors. For example, some students participated in anticipation of growth in important non-technical professional skills, such as communication, problem solving, critical thinking [13]. Other researchers have argued that motivation to engage in community service comes from altruistic motivation, egotistic reasons (e.g., gaining something personally), and social obligations [14]. Social obligations, which referred to one's sense of duty or responsibility, were found to have the highest positive effect on academic ability, self-confidence, public speaking, and writing abilities [14].

Research suggested students who participated in community engagement programs reported higher task-specific self-efficacy, as well as satisfaction in accomplishing tasks, than nonparticipants, thus boosting participants' self-confidence [5]. Additionally, their sense of belonging increased if they had friends in the same service-learning program [13] or were part of an academic service community [14]. In general, service program outcomes are thought to support student retention [1] [5] [8], The most prominent service participation outcomes were academic outcomes, such as persistence in college, GPA, and more constant interactions with faculty, which increased due to a students' participation in service [5]. Additionally, students also improved life skills such as social self-confidence, critical thinking, interpersonal skills, and knowledge and understanding of people from different races and cultures [5] [15].

Still, the ways that such opportunities could benefit students from historically minoritized backgrounds is underexplored. Research has consistently found that students from historically excluded backgrounds come to STEM environments pursuing opportunities for community service but frequently find those opportunities limited in conventional STEM education environments [16]. This was particularly concerning given that research suggested participation is particularly beneficial to students from historically excluded backgrounds. For example, in a service-learning program where Latinx computer science students engaged in STEM community outreach activities, Latinx women reported higher confidence when they knew that the skills they gained would be applicable in the real-world [17].

Outcomes of Engineering / STEM Programs

Existing engineering and robotics programs tended to focus on K-12 student and teacher experiences [18]. These outreach programs introduced K-12 students to engineering or science content, provided web-based resources for the classroom, or invited students to campus for 1-2 weeks [19]. As the primary focus was geared toward community partners, these programs often emphasized implementing the school's curriculum, rather than focusing on the undergraduate students' experiences. Other outreach programs focused on the retention of engineering teachers and accomplished this through professional development workshops and training potential teachers– that is, teaching prospective engineering teachers problem solving and engineering skills, or recruiting engineering majors into teaching professions. Still, the intended goals for most engineering programs were to increase engineering enrollment at the university level, diversify the engineering field, provide professional teacher development, and provide undergraduate student development [19].

Despite this, there were several programs that focused on the undergraduate experience. The Engineering Projects In Community Service (EPICS) engaged large student teams over various years to accomplish a community design project for academic credit [8]. Student participants self-reported how the EPICS grew their sociotechnical skills, including teamwork, organization, awareness of the community, and understanding of the design process. Interestingly, the technical skills reported by students were attributed to external experiences despite learning and using these technical skills for their community project [8]. In addition, the phrase "Engineering to Help" (ETH) has become popular in engineering experiences [20]. The justice-oriented view of ETH emphasized the importance of understanding the background and future implications of engineering projects; the authors suggested educators to foster empathy when creating these problems and involving stakeholders, community members, and policymakers in the decision-making process.

Methods

Setting, Participants, and Data Collection

The study was conducted at a private, highly selective, research university in the Northeast United States. In CR, the project coordinator, a graduate research assistant and member of the research team, pairs teams of 2-3 undergraduate students with teaching partners to address the specific computing education of their classrooms. For example, while one school asked for a track to teach robotics to a blind student with limited mobility, other schools asked for robotics classroom activities, mentorship for their students, and support for debugging. Undergraduate student teams spoke with their teacher partners, who worked in elementary and high schools, throughout the semester to learn the classroom's needs and collaboratively develop a solution for the partner school's request. Undergraduate students, the project coordinator, and the teacher partner met virtually every 1-2 weeks, depending on the teacher partner's availability, to provide updates on the project. CR provided all project materials, and reimbursed transportation costs (if any).

As the university that was the setting for this research provides extensive robotics education across the school of engineering in mechanical engineering, electrical engineering, computer science, and other departments, participants were recruited from across the school of engineering. As a result, participants in this research were undergraduate engineering students from across engineering and computer science disciplines. Students were expected to spend up to 10 hours per week on CR activities, including group meetings, meetings with teacher partners, field work (e.g., virtual or in-person visits), and preparatory work (e.g., preparing learning activities). A description of the student participants can be found in Table 1 in Appendix A. While most participants reported prior participation in service experiences during their K-12 education, some students expressed varying degrees of experience in engineering and computer programming. These students tended to have limited access to engineering and computer programming opportunities at their respective high schools.

Data in this research included one-on-one interviews with 6 undergraduate participants after a semester in the program. The interviews were video and audio recorded and lasted 60-90 minutes. Interview questions were developed around the Social Cognitive Career Theory. These interviews were conducted by the project coordinator and members of the research team. We asked students to discuss their experience in the program, similar activities in community engagement, teamwork experiences, and how their experiences might shape their thinking about their career plans. The purpose of these interviews was to examine how, if at all, community outreach had changed students' goals and motivations for their careers, as well as the ways their participation shaped their motivations for pursuing outreach opportunities in the future.

The purpose of the study was to offer students the opportunity to reflect on their learning after participating in the CR program. Specifically, we asked students to discuss their motivation for service learning, specific ideas about the way that they experienced service, and the ways that their personal identities, backgrounds, and values shaped their involvement. This research entailed a small N study of students' experiences in the CR program. As Pawley [21] suggested, small N engineering education research can support analyzing data intersectionality, as well as the interrogation of social power structures that form and structure students' experiences. We draw on 6 students' experiences to characterize the way their roles, responsibilities, and identities shaped their motivations for, and participation in, the CR community engagement program, focusing specifically on short- and long-term outcomes. All participants were assigned a pseudonym by the research team to protect their anonymity.

Data Analysis

We used thematic analysis to analyze the data, though our description of findings centered on 6 participants (Table 1). We developed a codebook inductively through iteratively reading, coding, and meeting to reconcile differences in codes (Table 2). The initial codes were derived from the theoretical framework guiding the study–Social Cognitive Career Theory [22]. SCCT is a conceptual framework used to examine undergraduates' career choice, bearing in mind how factors such as individual behaviors, expectations, and self-perceptions interact with environmental factors to construct their career choice.

Guided by the SCCT framework, the interview and codebook were designed to capture information about students' motivations and interests for joining the CR program and their perceptions about learning outcomes. We decided to center the students' motivations for community engagement and how it related to students' self-efficacy, outcome expectations, and post-graduation plans. As a result, findings described in this paper focus on students' perceived personal outcomes and career aspirations after participating in the CR program.

Findings

CR as a Mechanism for Social Change

All participants believed their involvement in community engagement contributed to social change. Participants saw this experience as a way to tackle representation issues within underrepresented communities. For example, participants mentioned how they saw robotics classroom activities contribute to exposing their school partner's students to engineering, potentially motivating the school to continue to invest in engineering education.

> ... the instructor would email us back saying how the students felt about the activity. So that's like letting us know that there's some kind of real world impact of what we did and enjoyed something… And a school is like, more involved in STEM, [is] likely to go down a STEM pathway.

Another participant saw their contributions in the classroom as providing access to STEM opportunities that historically, underrepresented communities may not have.

> I was working with students that mostly lived on the reservation, and so, historically, don't have as much access to STEM opportunities, so being able to help them is really something that contributes to a lot of change. … It's quite possible that the students that I was talking with during CR will go on to make some great contributions to the field of science or the field of advocacy, in trying to spread science to other underrepresented students.

Cultural Awareness: Learning About Others' Cultures and Perspectives

Undergraduates in this study often sought to learn about their school partner's culture and student body. One of the schools' student body was composed of Indigenous students, and the teacher aimed to make the elementary school students appreciate and learn about their own culture. To implement this, the undergraduates learned about the students' Indigenous cultural beliefs through a facilitator and merged students' Indigenous culture and engineering in their project implementation. Students that participated in this project tended to express that learning about other cultures formed a sense of scholar activism and social justice.

Other schools included majority Spanish speakers, making understanding code and the classroom activities difficult. The undergraduates' project entailed translating materials to Spanish, adapting and localizing engineering content to incorporate culturally relevant pedagogy.

Nathan, a first-year Data Science student at the time of the interview, partnered with a school on a reservation that asked him to help debug students' code and mentor students virtually. As Nathan was from a reservation, he described the experience as meaningful:

> So there were students in [CITY], which is where I'm from, or around where I'm from. So that meant a lot to me. They were Diné students, so some of them is my understanding were living on the reservation, which is also a cause that means a lot to me, that I'm helping them out too." [...] "I Can say 'Yá'át'ééh shí eí Nathan,' which means, 'Hi, my name is Nathan'

Nathan admitted he does not know the Diné culture and how this experience allowed him to directly learn from the Diné community, leading to a cultural awareness and desire to learn about other cultures and perspectives:

> ...I wanted to make sure that I was being respectful to their culture and not overstepping any boundaries. But when we started doing presentations or meetings with students and they were presenting to us, I realized that part of their culture was being inquisitive and just trying to learn. And so I felt that I was actually empowering their culture, rather than overstepping some boundary.

Nathan reflected that the learning process was embedded in culturally responsive pedagogy, emphasizing that he wanted to understand the culture and be intentional with his interactions with the students. He acknowledged his limited cultural knowledge and actively worked to avoid imposing external norms, showing a critical cultural awareness. This cultural awareness allowed him to validate Indigenous engineering practices, rather than privileging dominant educational practices. His realization that he was empowering, rather than overriding, students' culture highlighted the connection between cultural learning and social justice, reinforcing how community engagement can foster social change through respectful collaboration.

Another example of students' development of cultural awareness was demonstrated through Bradley, a third-year Mechanical Engineering student. His school partner was a school in Texas that asked for help creating robotics activities for the bilingual students. He identified language as an access point to engineering within the classroom:

> Yes, so part of it was, part of it was being able to translate the activities from strictly English to some of them in Spanish, some of them in Spanglish, to allow it for students be well, if the students only spoke Spanish or were struggling to learn English, they would be able to read … and do the activity. And then it also was having the activities be

> more about the Houston area to help them get adjusted to like, or help the students be able to relate back to the activity.

By translating activities into Spanish and Spanglish, Bradley acknowledged students' linguistic assets rather than framing language differences as barriers to learning. Through localizing engineering content, his team allowed students to visualize engineering concepts as relevant to their own communities, reinforcing student engagement and comprehension of the topic. Engineering instruction is shaped to align with students' linguistic backgrounds, and these adaptations positioned engineering education as not only accessible, but inclusive and equitable, thus reinforcing the goals of social justice-oriented teachings.

Bradley emphasized that centering activities in the Houston area reflected an effort to situate engineering learning within students' lived experiences. He said:

> So I do think it is the biggest one is understanding that these like engineering and CS things, they can be localized to a certain specific place, and understanding that a lot of the content that I learned is likely just localized for the Boston area, and that there can be a bigger a greater understanding in Engineering and Computer Science when working with people across the country and likely across the world, and understanding that although just the overall content is the same, the approach to the content can differ, and having that those unique perspectives can contribute to a greater sense of learning.

Bradley was reflecting how learning about other cultures and perspectives can result in students being more socially and critically conscious engineers. His emphasis on equality within engineering knowledge validated how there exists multiple ways of engaging with engineering and computer science. Furthermore, he mentioned how the perspective of his international teammate "provided their own unique perspective" to the design of the localized lessons. Although the engineering challenges were grounded in Houston, incorporating his team's viewpoints allowed the activities to be utilized beyond this context and into Boston-area schools. The collaborative process also reflected cultural learning through interacting with peers, where varying backgrounds contributed to more inclusive and flexible instructional design. Bradley reflected on his own childhood experiences in Houston to design meaningful learning experiences, connecting his technical learning to community and cultural experiences:

> So it was trying to embrace, what do I remember as a kid, growing up, enjoying and like, about the city, about, I guess, my perspective on like growing up, and then about the rodeo, and then, how can I create something like, How can I work to create something that helps these students achieve that same like, wonder." [...] "But I do know that school, as they were more in the city. They have, they have, like, their own, like things growing up, so likely, they were closer to rodeo, so the rodeo would have a larger impact on what these students experienced growing up than compared to my education.

Bradley recognized that the students' experiences may differ from his own, even within the same city, preventing overgeneralization and emphasizing diversity and the importance of understanding student's specific cultural backgrounds. Bradley's perspective shows that cultural awareness in engineering education involves recognizing language, place, and lived experiences as central to how students engage with technical content. By translating materials into Spanish and Spanglish, and localizing activities to the Houston area, he treated students' linguistic and cultural backgrounds as learning tools instead of obstacles. His reflections also demonstrated an emerging understanding that the engineering process is not universal, it is shaped by local and global context and perspectives. Because he collaborated with peers and adapted content, Bradley illustrated how culturally relevant pedagogy promoted inclusive engineering practices, deepened learning, and aligned engineering education with broader commitments to equity and social justice.

Community Engagement as a Professional Development Experience

While some saw their project as contributing to their own community, other participants viewed community outreach experiences as experiences that could foster non-technical professional skills. That is, multiple undergraduate students saw CR as a way to gain both technical and sociotechnical skills in the engineering field, serving as a professional development experience. Others described CR as a way to explore a subfield in engineering, particularly education, without committing to said subfield. This exploration was seen as important to their professional development, with implications for their pursuits of internships as inexperienced students. Involvement in CR was seen as an investment to students' career aspirations in engineering or computer science.

For example, at the time of the study, Andres was a first-year electrical engineering and computer science student. His school partner asked his team to create a series of robotics challenges for a high school engineering class and resources to help the students adjust to a new set of robots the school received that year. Andres's motivation for joining CR was based on his high school service experience and goals as an aspiring engineering professional:

> I was the type of person who said I'm going to do engineering … I'm not gonna do anything but engineering and things like [CR] or like the [Engineering Community Outreach Office], are very much like engineering, but like tangents. …. And then I pretty much noticed it's been a big part of my life, just like in communication. Despite not having any access to engineering education, it was me trying to go into that type of world and understand how people think, how I should approach engineering and stuff like that. And then now I actually get to approach, apply it in my own sense.

This instance described an undergraduate's view of deciphering how to enter the engineering field. Andres described CR as an extension of engineering. Andres's perspective provided insight into how students may approach engineering community engagement – as a way to enter engineering spaces and gain experience in engineering applications. He described how he initially viewed community outreach efforts as not traditional engineering, but rather, something tangential to engineering. He immediately described the goal of community engagement projects as something he's always been involved in, because of a lack of access to engineering education growing up. He described community outreach projects in engineering as their own world, with the goal being to learn how he "should approach engineering" – with a consideration of how technology and engineering affect local communities. Although initially Andres saw CR as a way to enter the engineering field, Andres's consideration for communities improved based on these experiences within engineering education.

Malik was a first-year computer engineering and math student working with the same school partner as Andres. When asked about his priorities in a future workplace, he stated experience was the most crucial to him as a first-year:

> As I am right now, I would probably put more in volume on what experience I could get from the company, because I'm at a point where I want to build up as much experience as I can and build up my technical knowledge as much as I can .. so that I can know enough that I can start actually creating things or going into the job market. I guess part one of my goals right now is to get an internship. To do that, I need some amount of experience, technical knowledge and ability to communicate adequately with whoever my interview is, whatever my team would ever be.

Malik organized his career goals into phases. The first phase was centered on obtaining technical skills and sociotechnical knowledge. He focused on what opportunities can provide to him, not what he could provide to an organization or company. As his goal was to enter the engineering industry, he was focused on obtaining experiences granting him communication and technical skills to make him a strong candidate for engineering internship experiences and ultimately, an engineering career. Giving back to the community was not a factor in Malik's decision to join CR – rather, the benefits of learning technical and sociotechnical skills and the experience in engineering convinced Mailk to engage with CR and service-related projects.

Emily was a first-year mechanical engineering student in CR. Her school partner in CR asked her to design a track for a robot. The track was expected to meet the special needs of a high school robotics student who had cerebral palsy, was blind, and had limited mobility. She mentioned how she was required to "do different things on campus" thanks to the project's design, in the form of using the campus's makerspace and working with different materials. A byproduct of this experience was learning to navigate technical and communication skills as a first-year student. Her experience in this program helped her realize her enjoyment with the technical aspects of engineering education. When asked if Emily would consider other community service outreach projects, she replied that she would consider these experiences because she enjoyed them and they were" good experience for resumes, like jobs, like in general". In both Emily's and Malik's cases, community engagement projects were seen as resume builders for their prospective careers.

Discussion and Future Directions

Undergraduates in CR exemplified a better understanding of cultural awareness based on their school partner's location and culture, while also demonstrating an intention to incorporate this perspective into their future professions. While Nathan's outlook focused on understanding the students' culture, and Bradley's through language, allowing students to understand the material, their experiences with their school partner brought into their mind how and who engineering can be accessed by. The motivations for joining community engagement projects were focused on professional development and the technical and sociotechnical aspects learned through the experience. Undergraduates mentioned that joining CR, especially as first-year students, was a strategic move to obtain experience in the field and add to their current resume to secure an internship. Despite the initial motivation, most participants expressed an intention to incorporate their engineering perspective with consideration to how communities and users are affected by it. The findings suggested community engagement was an activity that built students' understanding of the communities around them and provided sociotechnical skills that would be useful to their future careers. As interviews were held by the project coordinator, it is possible that students withheld their full opinion about the program. Further research is needed to determine other outcomes from community engagement programs, including technical skills and individuals' perception of social change. CR will continue to conduct research on undergraduate engineering and computer science students to investigate these questions and address to better meet undergraduates' perceived personal and technical outcomes from community engagement programs.

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Appendix

Table 1: *Participant Information*			
Name	Year	Major	Involvement
Bradley	Third-year	Mechanical Engineering	Robotics Club and the Wind Ensemble
Nathan	First-year	Data Science	Data Science Club, Society of Physics Students, Linux Club
Andres	First-year	Electrical Engineering / Computer Science	Robotics Club, Mechanical keyboard club, IEEE, engineering outreach program, Society of Latinx Engineers
Emily	First-year	Mechanical Engineering	Electric car racing team, Engineers Without Borders
Malik	First-year	Computer Engineering/ Mathematics	Mechanical keyboard club, IEEE

Table 2 *Example Codes*		
Parent Code	**Child Code**	**Description**
Service-related Outcomes	Social Impact	Participant references how their project relates to social change OR how their involvement can lead to social change.
	Personal Impact	Participant mentions how community outreach/service has affected themselves.
	Cultural Consideration	Participant mentions consideration for a culture not their own.
Career Aspirations	Industry	Participant expresses consideration or interest of entering industry
	Company Service Initiative	Participant mentions service as part of the company responsibilities they are part of in the future
	Potential subject/ disciplinary paths	Participant expresses interest in following other disciplinary paths